

SSL R&D in Key Countries Investments, Patents, and Publications

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Agenda

- I. Project Background and Context
- II. Quantifying the Relative Position of US and International Solid-State Lighting
 - ☐ R&D investments
 - ☐ Science indicators – simple segmentation
 - ☐ Science indicators – complex segmentation



Strategic Perspectives, Inc.

- Management consulting firm focused on scientists and research organizations

- Founded 1980
- Geographically distributed



- Services include

- Market intelligence
- Competitive intelligence
- Project strategy
- Program development
- External advisory boards
- Commercialization activities
- Best practices in research management



- Project experience in a range of areas

- Bioscience
- National security infrastructure
- SSL



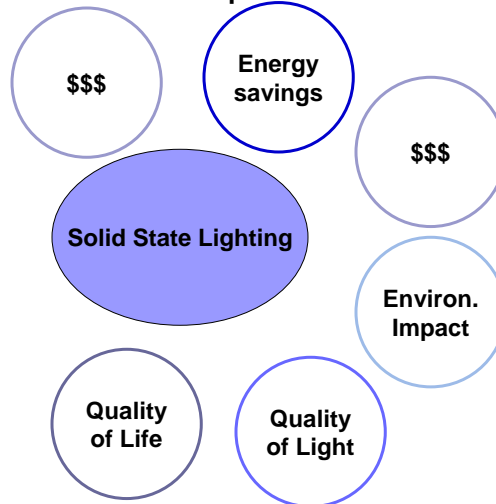
I. Background and Context

- I. Project Background and Context
- II. Quantifying the Relative Position of US and International Solid-State Lighting
- III. SSL Research Activity



2006/2007 – Pivotal Period for SSL Research and Industry for National Competitiveness?

- Compelling value proposition
- Disruptive innovations provide opportunities for aggressive players to improve their position in an industry
- Lighting as perhaps the most entrenched industry in business
- SSL track record of incremental technical improvement



SSL has a classic window of opportunity, which may not close until after 2007 – but it will close



Quantifying SSL Activity in Leading Countries

- DOE motivation for the project
 - Raise the level of common understanding in DOE and US industry with respect to international strengths
 - Add rigor to conventional wisdom
 - Provide a baseline for future comparisons
- Major project activities
 - Analyzed the US competitive position in terms of inputs (i.e., R&D \$) and outputs (i.e., patents, publications)
 - Assessed whether other countries are putting a higher priority on SSL
- Major deliverables
 - Catalog of R&D activities and investments of leading countries
 - Dataset of >50k electroluminescence-relevant patents/publications
 - Segmentation model for looking at sections and subsections of the dataset
 - Tools and infrastructure for analyzing dataset in terms of contributors (country/company/individual), time progression, topics, etc.

Tools built to assist in quantifying international S&T SSL strength are suitable for numerous applications



US and International SSL

- I. Project Background and Context
- II. Quantifying the Relative Position of US and International Solid-State Lighting
 - R&D investments
 - Science indicators – simple and complex segmentation
- III. SSL Research Activity



How to Derive Geographic R&D Levels?

- Multiple categories
 - Programs exclusively targeting SSL
 - Programs targeting SSL and other areas
 - General R&D that relates to SSL
- Data relatively available
 - Consistency problems in screening projects for inclusion
- Important to match quantitative data with a qualitative “feel”
 - Momentum and interest in further program spending may be as important - or more – than current spending.
- R&D \$, relative ratios of SSL to general R&D, are informative indicators of strategic focus

Government R&D

- Multiple categories
 - Companies exclusively focused on SSL
 - Companies targeting SSL and other opportunities
 - Companies doing work that relates to SSL
- Largest companies are (by definition in an emerging market) not pure-plays; estimates based on:
 - Regulatory filings
 - Company size / funding
 - Public commentary on R&D
- Corporate R&D often includes product development efforts

Industry R&D

R&D capacity metrics are estimates – and intended for use in conjunction with other analysis



SSL R&D Investment Activity

- Research investment “focused on, or significantly applicable to, Solid-State Lighting”
- Different from market research #'s
- Data inherently imprecise

	LED	OLED
Taiwan	\$39M	\$4M*
Korea	\$48M	\$18M*
China*	\$77M	\$4M
Japan	\$166M	\$31M
Asia	\$330M	\$67M
Europe	\$62M	\$106M
N. America	\$171M	\$48M
TOTAL	\$562M	\$238M

* Likely undercounted - lack of transparency

Taiwan

- Highly strategic industry
- Cooling expectations for SSL
- IP sensitivity relative to China

Korea

- Consumer electronics / displays as a significant factor
- Government-funded industrial development

China

- Conservation critical for economic development
- Not a replacement market
- National and regional industrial development plans

Japan

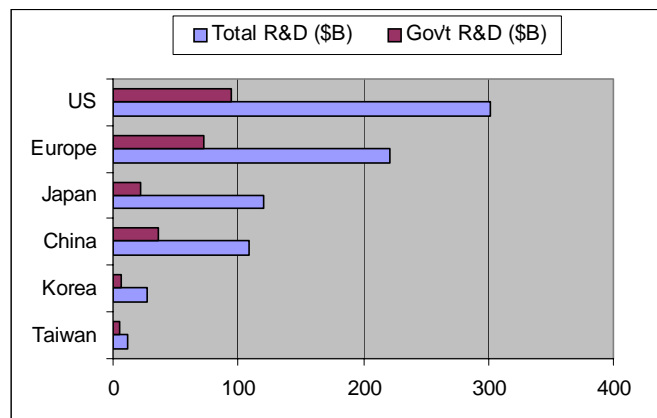
- Light for the 21st Century - \$50M over 5 years
 - Mixed views within METI/NEDO on program efficacy
 - No apparent commitment to fund follow-on phases
- Industry is likely mature enough to carry the load

Europe

- Industry heritage
- EU-wide efforts (via FP6) slanted towards OLEDs (and displays)
- Large variations between countries

Overall R&D Activity by Country in Absolute \$

10



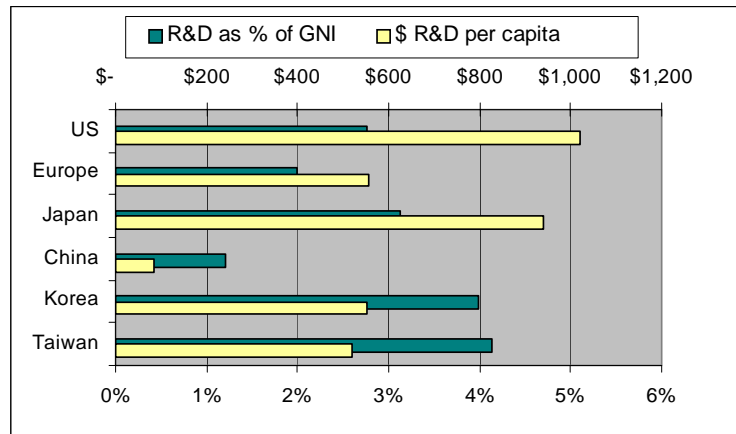
Source: Battelle/R&D Magazine, World Bank

Clear US leadership?



Overall R&D Activity by Country in Relative \$

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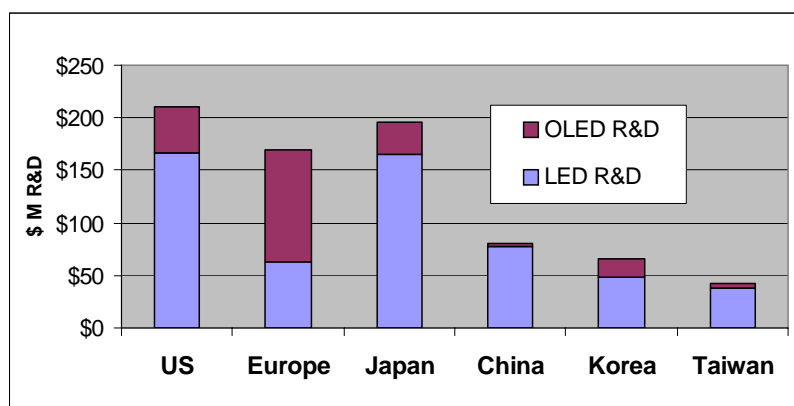


US leadership based on heritage and national wealth as well as ongoing prioritization



SSL R&D Activity by Country – Absolute \$

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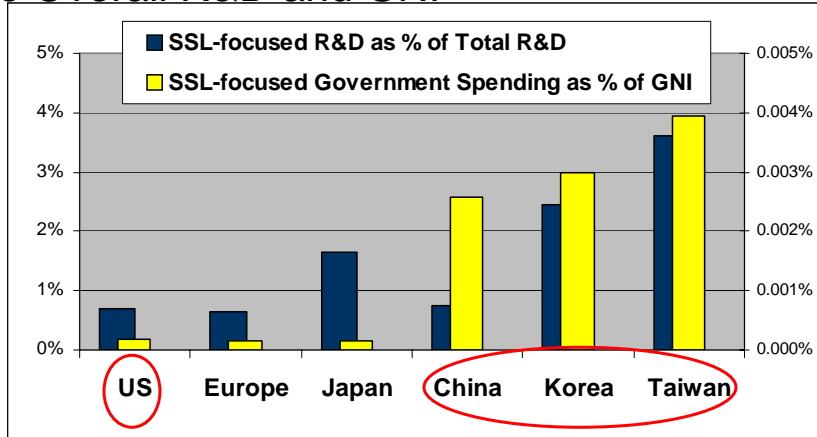


Very significant US presence



SSL R&D Activity by Country – \$ Relative to Overall R&D and GNI

13



Select Asian countries putting a high priority on investments in SSL



US and International SSL

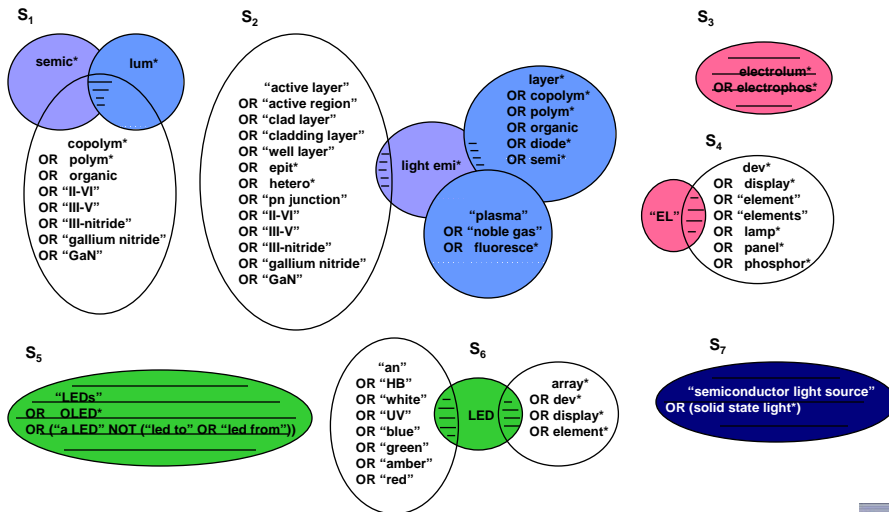
14

- I. Project Background and Context
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 - R&D investments
 - **Science indicators**
- III. SSL Research Activity



A Comprehensive and Accurate Search Strategy is Critical

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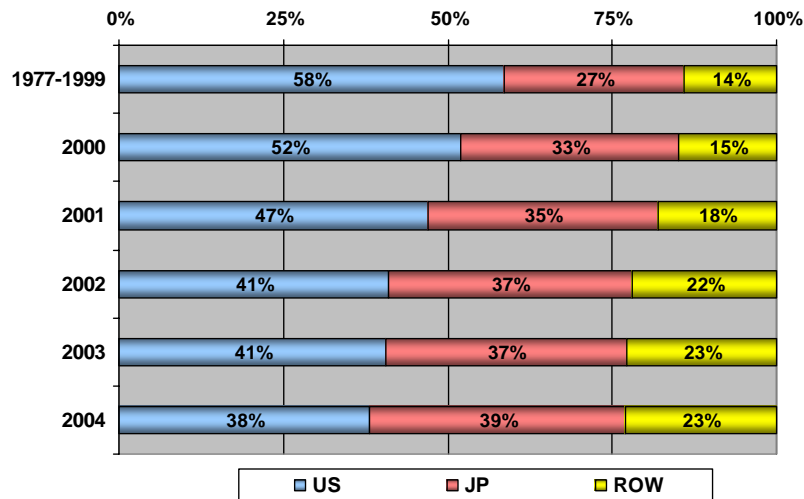


Estimated dataset quality: greater than 80% of relevant items, less than 5% irrelevant items



Trends – US Share of SSL Patents

16

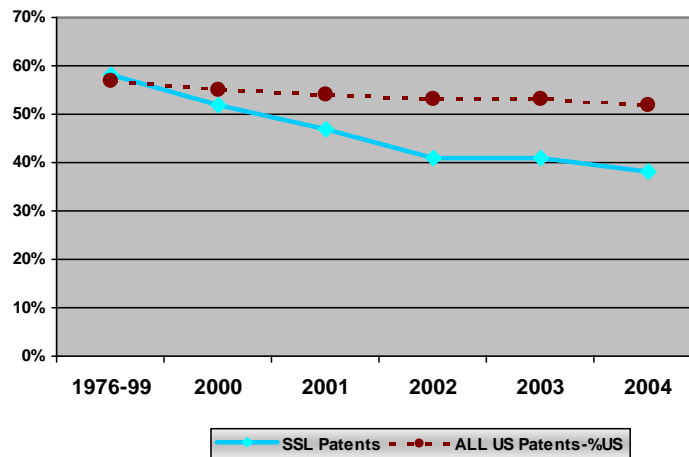


US share declines significantly in the last 5 years



Erosion of US Share of Patents – SSL and All

(Base for SSL Patents: 10,505 in Superclusters, LEDs and OLEDs)

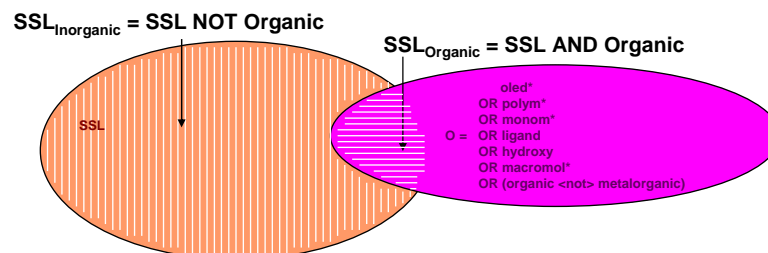


US share loss within LED / OLED not explainable by broader patent source trends



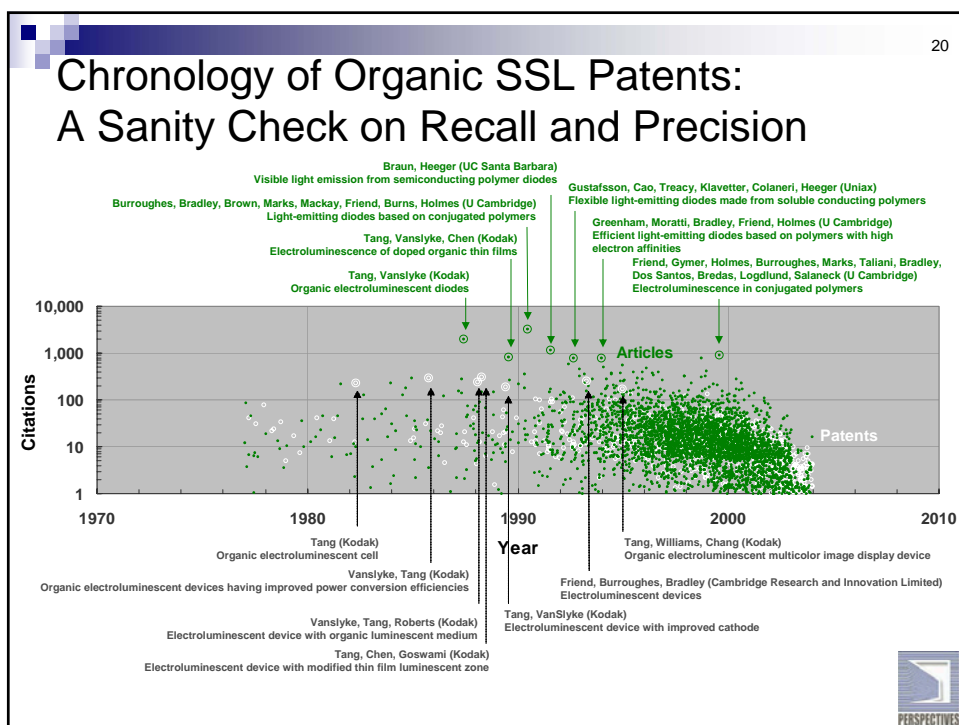
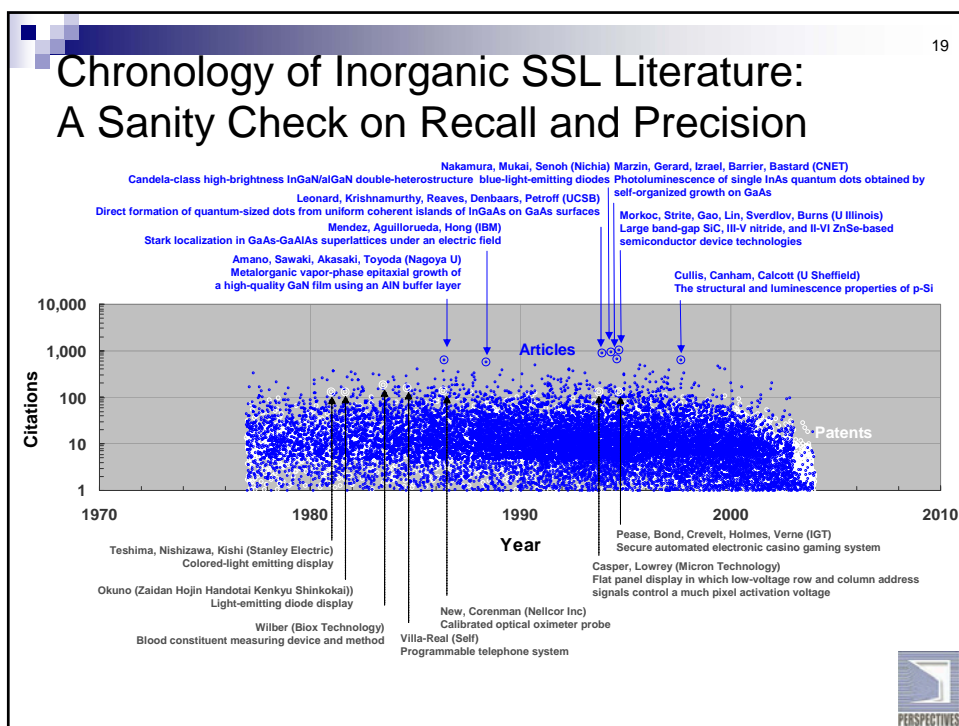
Simple Partitioning Enables Useful Analysis

- Challenge with such a wealth of data (~50k records) is in selecting segments for discrete analysis
- Some partitioning is relatively straightforward, based on source data or simple derivations
 - Fielded data - date, author/inventor, institution, country, continent
 - Organic vs. Inorganic

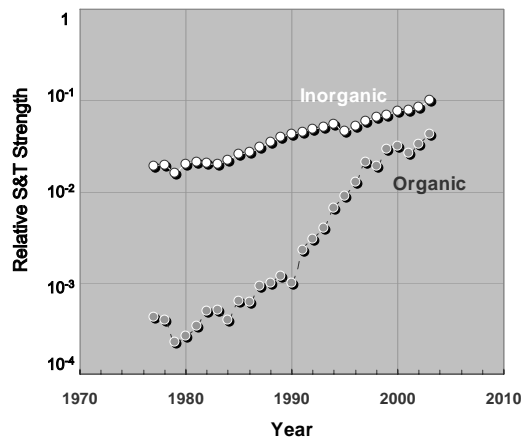


Simple partitioning allows analysis of trendlines across certain dimensions, including country or origin





Inorganic vs. Organic SSL



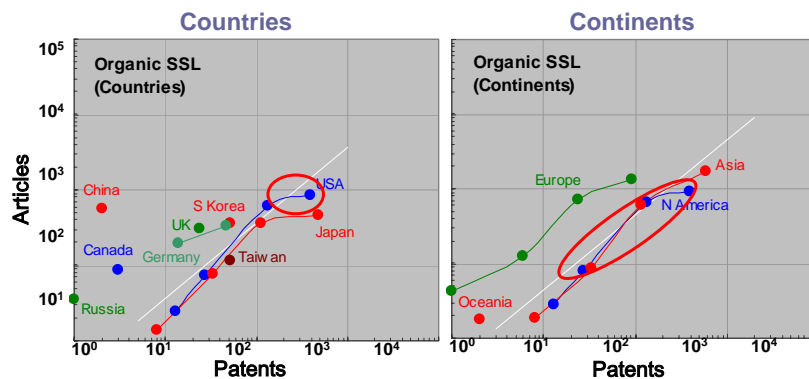
	Inorganic	Organic
Articles 1977-2003	25,158	6,466
Patents 1977-2003	9,446	1,452

- Note logarithmic scale
- Relatively consistent slopes over time

Given pace of S&T in organic, relative strengths could intersect as early as 2010



Trends – Organic

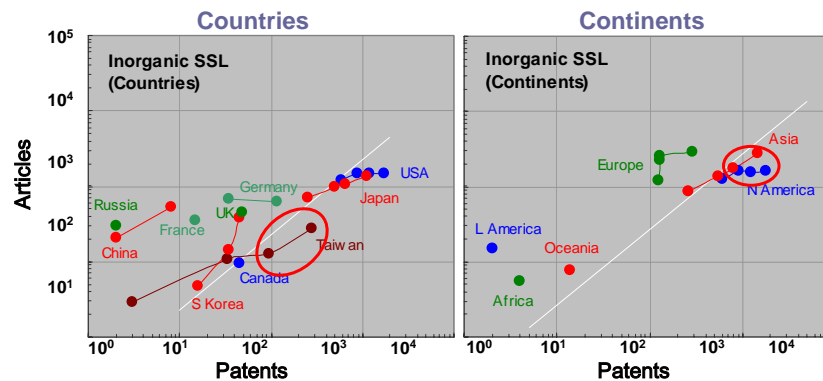


- Note log scale
- Each line segment shows 5 years' activity
- China with a surprisingly strong start in literature
- Japan pursuing patenting

Continued US high activity level – but worrisome signs from overall organic scientific activity



Trends – Inorganic



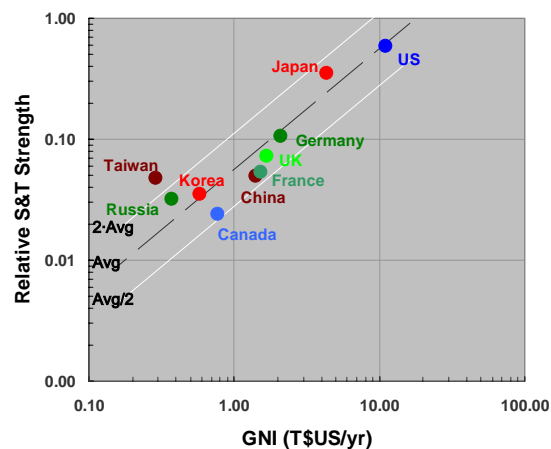
- Note log scale
- Each line segment shows 5 years' activity
- Asia extremely strong in recent literature
- US with a shrinking lead

Continued US high activity level – but worrisome signs from overall inorganic scientific activity



SSL Strength Normalized to GNI

- Note log scale
- Asian countries again fare well:
 - Taiwan, Japan, and Korea above-average
 - China handicapped by not playing in patenting process



Countries putting a priority on SSL are predominantly Asian



Complex Partitioning Can Yield Actionable Information

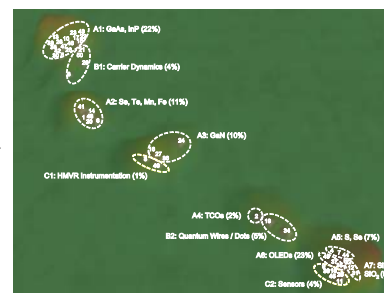
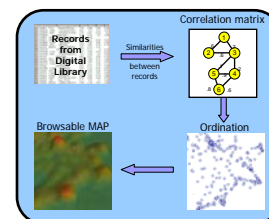
- Making judgments based on a 50,000 record database is inherently over-generalizing
 - Impossible to have an intuitive grasp of such a large number of records
 - Comparing many un-like entities (e.g., fishing lures and die construction and phosphor compositions)
- Not feasible to divide records manually
- Current classification systems are not acceptable
 - USPTO and IPC patent classifications exist, but are not widely accepted
 - There are no universal literature classification systems
- Thus, we cluster the literature and patent data at multiple levels, giving rise to emergent categories that
 - Break the data into more meaningful categories
 - Allow us to define past and current topics and their histories
 - Allow us to define “hot” topics, see who (countries, companies) is doing the work, anticipate short-term trajectories, and determine our own responses

Desirable to automatically group records based on inherent similarities



Complex Partitioning is Mathematically Based

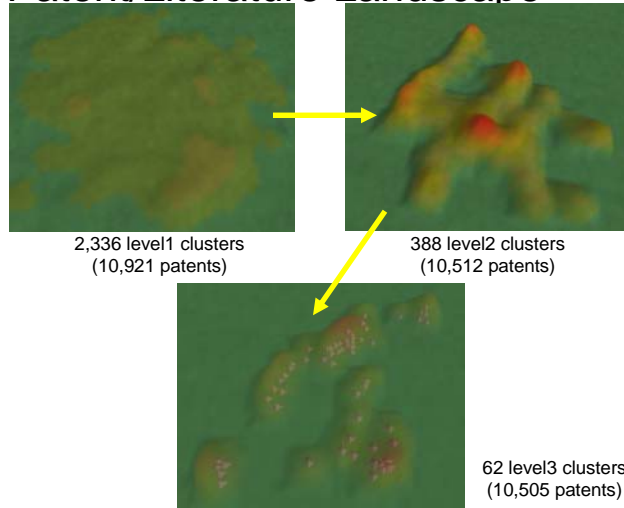
- Cutting edge 2-D clustering techniques using the citation structure
 - Five recent publications in the scientometrics field (Boyack, Klavans and others)
- Recursive clustering based on citations gives an emergent structure
 - Intermediate level gives groupings that correspond to “topics” of research
 - High-level “superclusters” give groupings that break the data into more meaningful chunks than simple partitioning
- Data at each level of clustering can be shown as a “map” and explored using Sandia’s VxInsight tool



Successive Clustering Gives Different Views of the Patent/Literature Landscape

27

- Clustering useful to segment large dataset into smaller, self-defining groups
- Orientation is exceedingly cumbersome



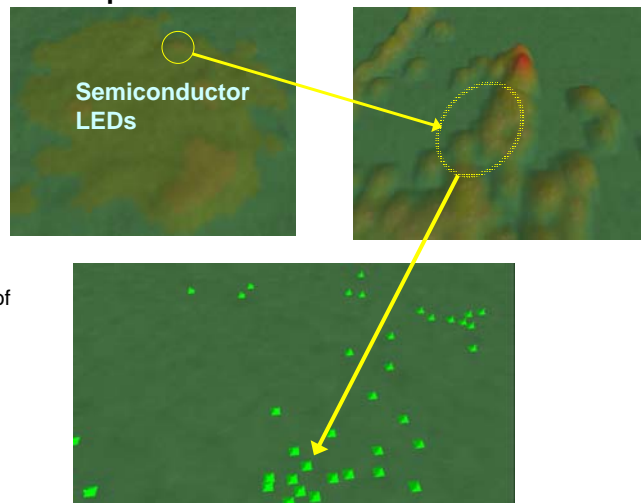
Good maps should be intuitive, but also lead to counterintuitive analysis



Maps Enable Exploration

28

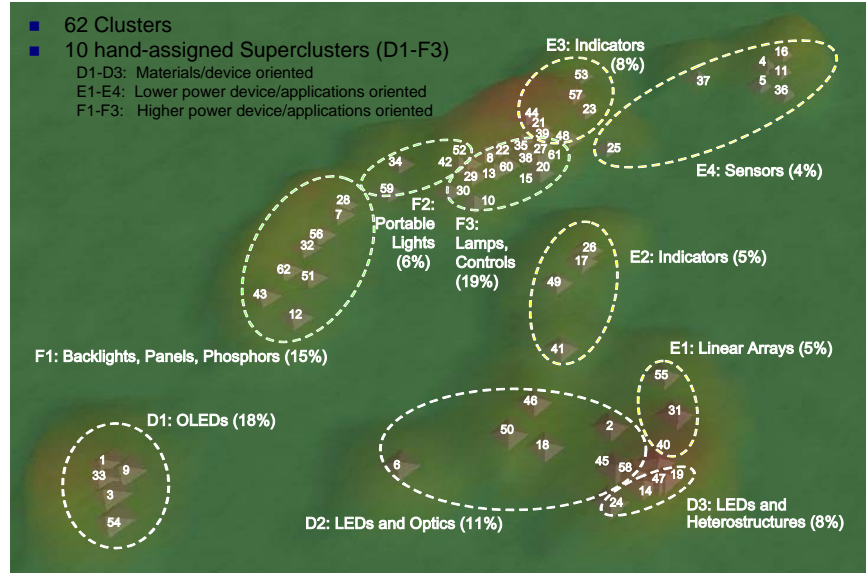
- A closer look at the semiconductor LED cluster shows twin peaks and other distinct topography
- Each area can be analyzed
- Each of the pyramids represents a cluster of clusters of patents, representing anywhere from 4 to 200 total patents
- Individual pyramids can be explored and referenced back to underlying data



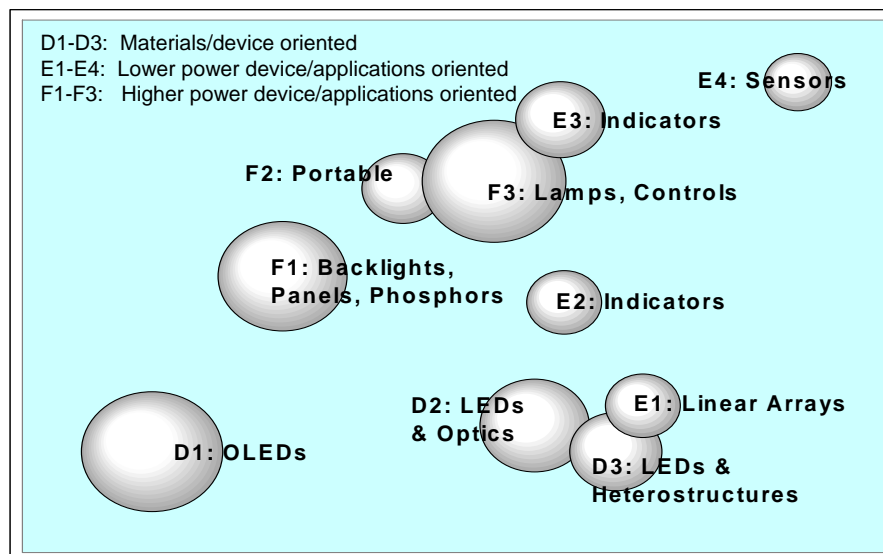
Ability to link back to underlying records enables exploratory analysis



End Result: Annotated Clustered Patent Map



Patent Superclusters – Stylized Representation



Findings

- Investment levels are worrisome
- Research indicators tracking raises more cause for concern
- Specific research activity within particular topics is alarming
- US research capacity is still world-leading



Leading Companies in Patent Superclusters

F3: Lamps & Controls (n=927)

(top companies, not all have 3%+)

Philips - Koninklijke Philips Ele	2%
Gelcore Company	2%
911 Emergency Products, Inc.	2%
Color Kinetics Incorporated	1%
Koito Manufacturing Co., Ltd.	1%
Matsushita Electric Industrial C	1%
IBM Corp	1%
Lumileds Lighting U.S. LLC	1%
Texas Digital Systems, Inc.	1%

F1: Backlights, Displays (n=512)

Denso Corporation	4%
Durel Corporation	4%
TDK Corporation	4%
Osram Sylvania Inc.	4%
Matsushita Electric Industrial C	3%
NEC Corporation	3%

E3-Indicators (n=207)

Hon Hai Precision Ind. Co., Ltd.	10%
PPT Vision, Inc.	3%
Welch Allyn Inc.	3%

E4: Sensors (n=127)

Xerox Corporation	7%
E.O. Schweitzer Manufacturing	6%
Sensidyne, Inc.	4%
Hewlett-Packard Company	3%
Masimo Corporation	3%

E2-Indicators (n=154)

Nichia Corporation	23%
Rohm Co. Ltd.	5%
Citizen Electronics Co., Ltd.	5%
Sony Corporation	3%
Philips - Koninklijke Philips Ele	3%
Seiko Epson Corporation	3%
Samsung Electro-Mechanics C	3%

E1-Linear Arrays (n=146)

Oki Data Corporation	9%
Canon Kabushiki Kaisha	6%
Oki Electric Industry Co., Ltd.	5%
Xerox Corporation	5%
Kabushiki Kaisha Toshiba	4%
Sharp Kabushiki Kaisha	3%
Sony Corporation	3%

D1: OLEDs (n=1403)

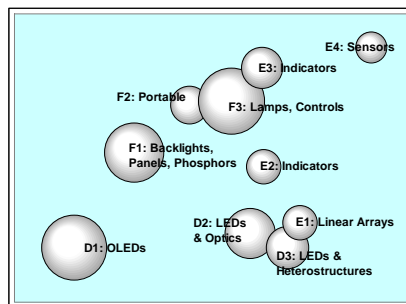
Eastman Kodak Company	7%
Semiconductor Energy Labora	6%
NEC Corporation	4%
TDK Corporation	4%
Sanyo Electric Co. Ltd.	4%
Idemitsu Kosan Co., Ltd.	3%

D2: LEDs & Optics (n=536)

Lumileds Lighting U.S. LLC	6%
General Electric Company	5%
Sharp Kabushiki Kaisha	6%
Kabushiki Kaisha Toshiba	5%
Rohm Co. Ltd.	4%
Matsushita Electric Industrial C	3%
Osram Opto Semiconductors C	3%
Toyoda Gosei Co., Ltd.	3%

D3: LEDs and Hetero. (n=464)

Sharp Kabushiki Kaisha	9%
Kabushiki Kaisha Toshiba	7%
Sony Corporation	7%
Toyoda Gosei Co., Ltd.	6%
Lumileds Lighting U.S. LLC	5%
Rohm Co. Ltd.	5%
Showa Denko K.K.	4%
Matsushita Electric Industrial C	4%

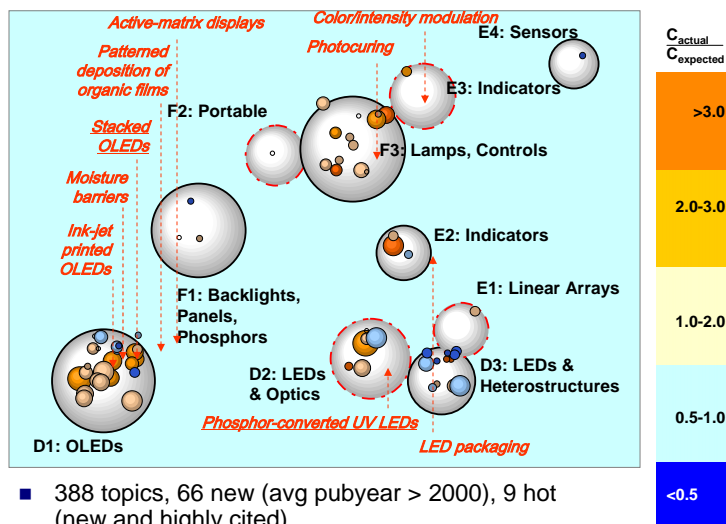


Leading International Patent Assignees, All vs. Last 5 Years

1976-2004 - Top Companies		2000-2004 - Top Companies		Change	% in Last 5 Years
Name	Share	Name	Share		
Canon Kabushiki Kaisha	1.1%	Canon Kabushiki Kaisha	1.1%	107%	48%
Fuji Photo	0.7%	Fuji Photo	1.1%	159%	71%
Kabushiki Kaisha Toshiba	1.8%	Kabushiki Kaisha Toshiba	1.7%	93%	41%
Matsushita Electric	1.4%	Matsushita Electric	1.7%	122%	55%
Motorola	1.3%	Motorola	0.6%	41%	19%
NEC	1.6%	NEC	2.0%	130%	58%
Philips (except Lumileds)	1.8%	Philips (except Lumileds)	2.7%	148%	66%
Rohm	1.0%	Rohm	1.4%	137%	61%
Sanyo Electric	0.9%	Sanyo Electric	1.5%	164%	73%
Seiko Epson	0.6%	Seiko Epson	1.4%	213%	96%
Semiconductor Energy Lab	0.9%	Semiconductor Energy Lab	1.9%	207%	93%
Sharp Kabushiki Kaisha	2.4%	Sharp Kabushiki Kaisha	2.1%	90%	40%
Sony	1.4%	Sony	2.2%	156%	70%
TDK	0.9%	TDK	1.8%	204%	91%
Toyoda Gosei	0.8%	Toyoda Gosei	1.1%	130%	58%

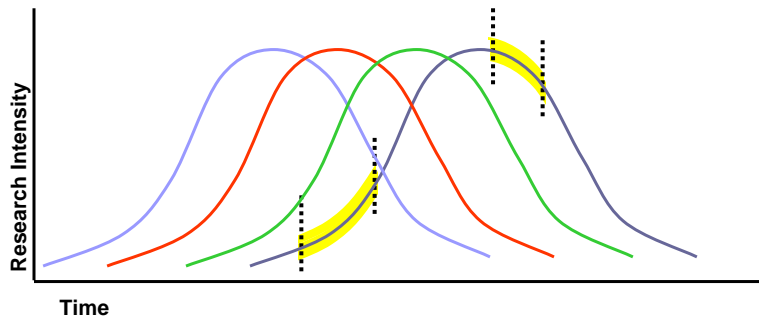


What / Where are the Recent Patent Topics?



- 388 topics, 66 new (avg pubyear > 2000), 9 hot (new and highly cited)
- 7 drawn from OLEDs, lamps/controls superclusters
- 2 drawn from LEDs/optics and relays/indicators/games superclusters

Lifecycle of Clusters within Scientific Literature



■ Bell Curve-like lifecycle

- Breakthrough paper -> significant activity -> maturation -> tailing off
- New clusters pick up momentum, are incorporated into other research areas, or are left for more productive areas

Potential for early identification of gathering and peaking clusters

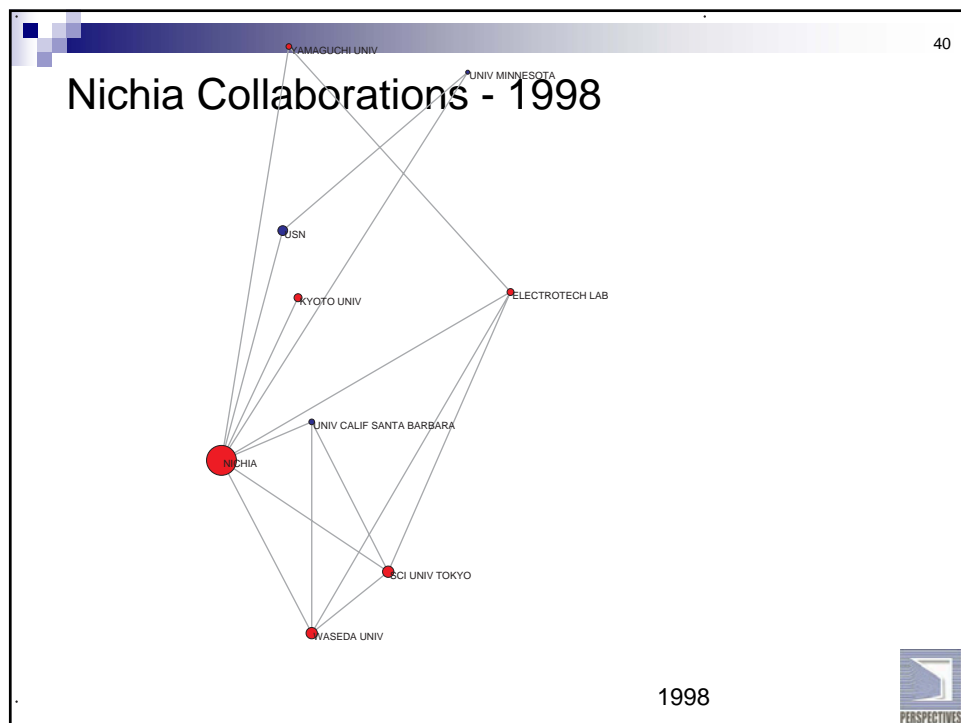
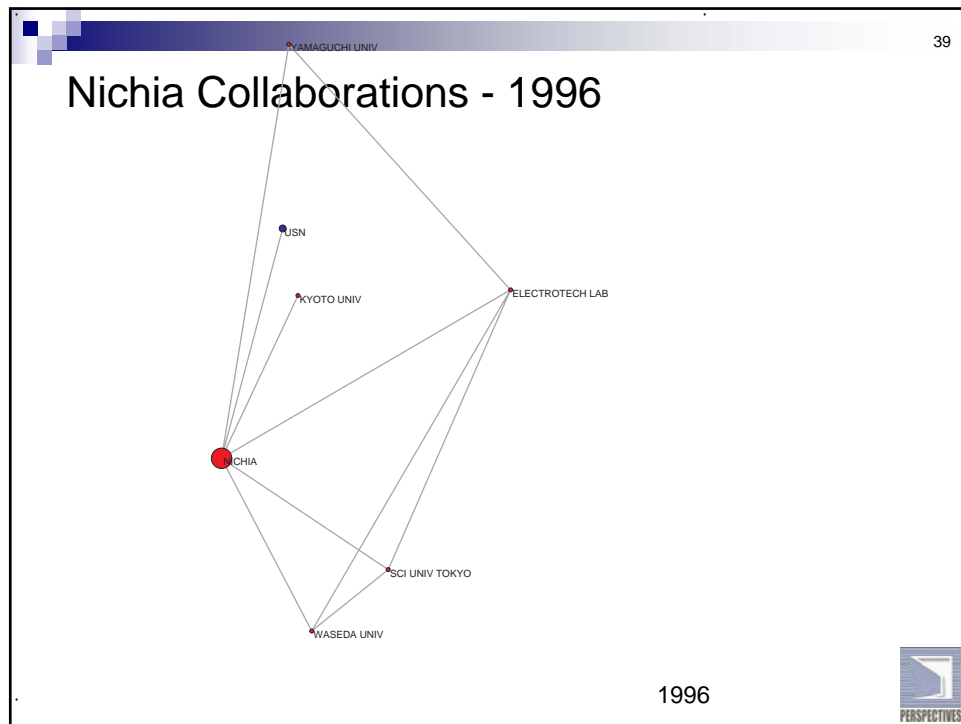


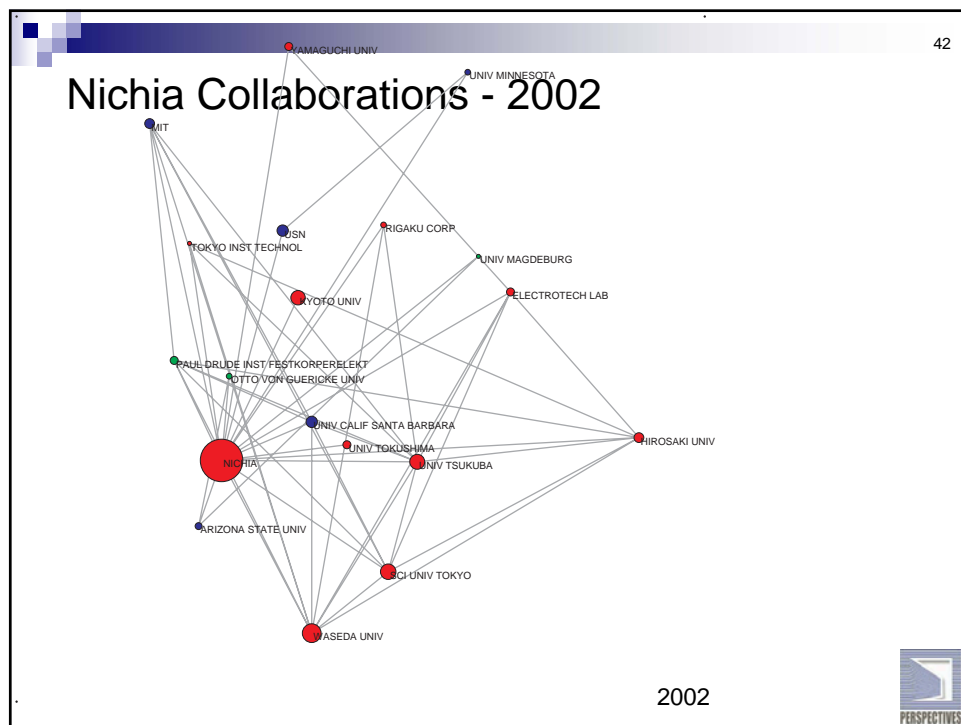
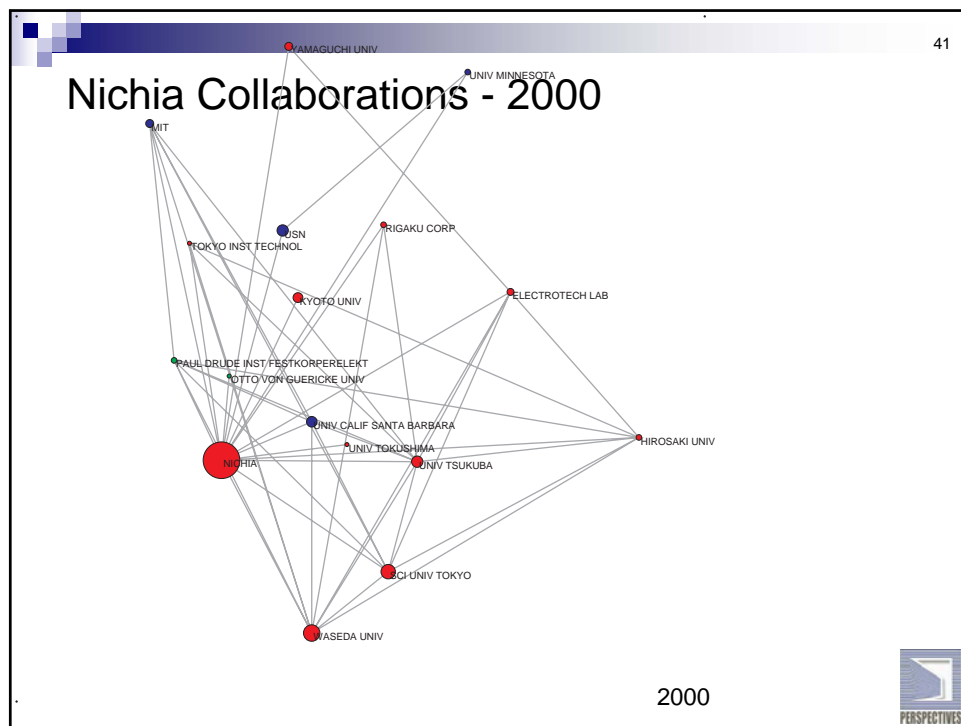
Nichia Collaborations - 1994

● NICHIA

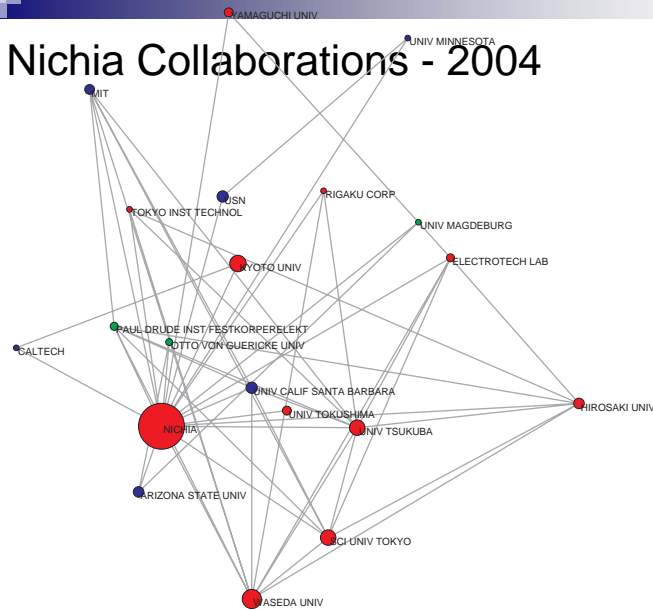
1994







Nichia Collaborations - 2004



Nichia's growth over time reflected in increasing US partnerships

43



How Can the Dataset be Used by the US SSL Community?

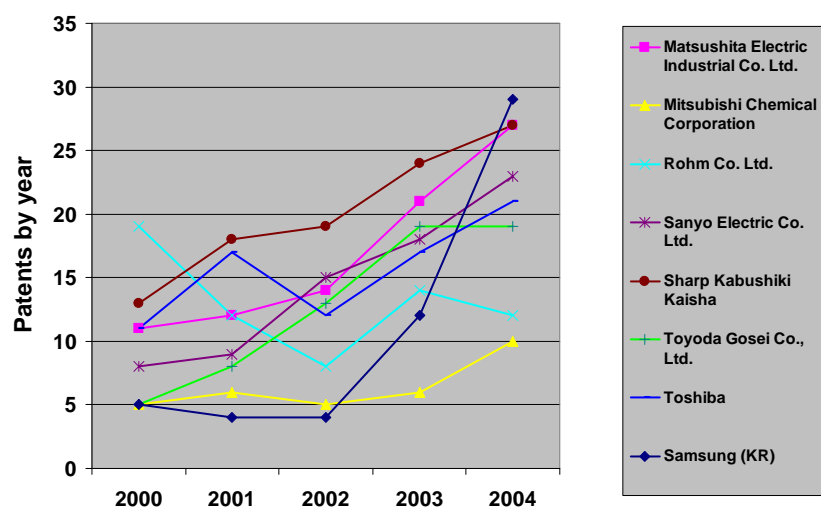
- ☐ What topics have recently peaked?
- ☐ What topics are about to emerge?
- ☐ What overseas researchers / institutes / companies are active in your field?
- ☐ What is your portfolio position relative to others?
- ☐ What overseas companies are moving towards your patent portfolio?

44

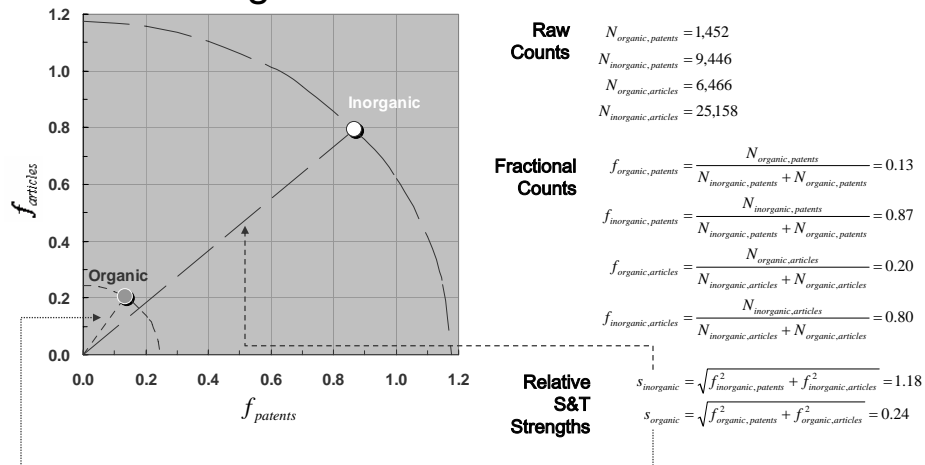




Recent Patenting, Selected Asian Companies



Methodology - Calculating Notional “S&T Strengths”



Reasonable to derive relative S&T strengths for organic and inorganic and use for comparative analysis



Patents vs. Articles

- Note log scale
- Sci-lit as leading indicator
- Patents generous to US

